
FLAT WALL INSULATING CONCRETE FORM (ICF) CONSTRUCTION: 2019 CBC

Disciplines: All

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PURPOSE

This Interpretation of Regulations (IR) clarifies requirements, specifications, inspections, testing, and acceptance criteria for the use of flat wall Insulating Concrete Forms (ICF) in cast-in-place concrete wall construction on DSA projects.

SCOPE

This IR is applicable to flat wall ICF systems, which result in a solid, flat reinforced concrete wall between insulation panels interrupted only by plastic or metal cross-ties. This type of ICF system is addressed in California Building Code (CBC) Section 1903A.4. This IR is not applicable to other ICF systems such as waffle grid, screen grid, and post-and-beam systems. Refer to the American Concrete Institute (ACI) Report on Design and Construction with Insulating Concrete Forms (ACI 560R) for further description of typical ICF systems.

ICF are, by nature, proprietary products with a certain degree of variation between different manufacturers. Additionally, new ICF products may result in future innovations unforeseen at the time of this writing. While this IR endeavors to address flat wall systems in a general sense applicable to products from multiple manufacturers, DSA will make the final determination of applicability of this IR to any specific manufacturer's product.

BACKGROUND

Flat walls built with ICF systems are structurally designed and constructed similar to cast-in-place walls built using removable forms. The wall assembly consists of reinforced concrete between two insulation panels that serve as formwork during concrete placement. The insulation panels are typically flame-resistant expanded polystyrene (EPS) material connected by plastic (i.e., polypropylene) or metal cross-ties. Depending on the specific product, flat wall ICF may be a block system, panel system, hinged system, or plank system. Refer to ACI 560R and product data for additional information.

ICF systems typically are available to accommodate concrete wall thicknesses of 4", 6", 8", 10", or 12" with insulation panels ranging from 2-3/8 to 2-3/4 inches thick. In the commonly used block system, units are typically 12 to 24 inches tall and 48 to 96 inches wide and laid in running bond. The cross-tie webs span the concrete core and connect to vertical cross-tie flanges embedded within the insulation panels. The face of the flange is recessed from the outer faces of the insulation panel and extends the full height of the wall to facilitate fastening of interior and exterior wall finishes. The cross-tie webs are often designed to secure the position of horizontal steel reinforcement in the form cavity.

1. DESIGN

The structural design of flat wall ICF systems shall comply with the CBC, ACI Building Code Requirements for Structural Concrete (ACI 318), and this section. ICF walls are permitted in one- and two-story buildings only. Refer to Sections 5 and 6 below for fire and life safety and accessibility requirements, respectively.

FLAT WALL INSULATING CONCRETE FORM (ICF) CONSTRUCTION: 2019 CBC**1.1 Evaluation Report**

ICF systems shall be qualified by an evaluation report in accordance with *IR A-5: Acceptance of Products, Materials, and Evaluation Reports*. The evaluation report shall document compliance of the system with the requirements of American Society for Testing and Materials (ASTM) E2634: Standard Specification for Flat Wall Insulating Concrete Form (ICF) Systems and International Code Council Evaluation Service (ICC-ES) AC353: Acceptance Criteria for Stay-In-Place, Foam Plastic Insulating Concrete Form (ICF) Systems for Solid Concrete Walls.

1.1.1 The evaluation report shall qualify the system for use in the Seismic Design Category (SDC) of the project except as permitted in Section 1.3 below.

1.1.2 EPS panels shall comply with the requirements for foam plastic insulation per CBC Section 2603 and ASTM E2634.

1.2 Shear Strength

Cross-ties consist of webs that span horizontally across the concrete core and flanges that are embedded vertically in the insulation panels on both sides. The embedded cross-tie webs reduce the concrete area. The Structural Engineer of Record (SEOR) shall provide calculations to address concrete shear strength reduction in consideration of the area of concrete displaced by the cross-tie webs. A percentage of effective concrete area shall be calculated in both the horizontal and vertical planes. The concrete area (A_{cv}) used to calculate shear strength per ACI 318 Equation 18.10.4.1 shall be reduced by the most critical percentage.

1.3 Seismic Force Resisting System

The seismic design factors given in American Society of Civil Engineers Standard 7: Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE 7), Table 12.2-1 for concrete shear wall systems are based on concrete shear walls constructed with traditional formwork. Shear walls constructed with ICF have numerous closely spaced planes of discontinuity due to the presence of cross-tie webs, and there is a lack of test data to demonstrate the equivalence of this condition with conventional shear walls. Concrete walls constructed in ICF systems and serving as the primary seismic force resisting system shall be designed in accordance with one of the following three approaches.

1.3.1 ICF shear walls may be qualified for use as “special reinforced concrete shear walls” by the evaluation report. The evaluation report shall document compliance of the system with the requirements of Section 3.2.3 Item 8, Section 4.2.2.6, and associated requirements of ICC-ES AC15: Acceptance Criteria for Concrete Floor, Roof and Wall Systems, and Concrete Masonry Wall Systems.

1.3.2 ICF shear walls may be designed as “special reinforced concrete shear walls” when approved by DSA as an alternate method of construction in accordance with California Administrative Code (CAC) Section 4-304. Prior to submission of the project and in accordance with *PR 18-01: Request for Alternate Design, Materials and Methods of Construction*, the project applicant shall submit and obtain DSA approval of form *DSA 1-AMM: Request for Alternate Design, Materials and Methods of Construction*. When conforming test data is available, compliance with FEMA P-795: Quantification of Building Seismic Performance Factors: Component Equivalency Methodology (FEMA P-795) can be used to justify design as a special reinforced concrete shear wall system. DSA may require a peer review of the test data and documentation in accordance with FEMA P-795 Section 2.9. When required, the peer reviewer shall be acceptable to DSA.

1.3.3 In lieu of either approach in Section 1.3.1 or 1.3.2 above, DSA will permit a prescriptive design of the seismic force resisting system as follows:

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1.3.3.1 In consideration of the lack of test data, seismic design factors, including the Response Modification Coefficient (R), Overstrength Factor (Ω_0), and Deflection Amplification Factor (C_d), used to determine seismic force demand and associated seismic acceptance criteria shall be taken from ASCE 7 Table 12.2-1 for an “ordinary reinforced concrete shear wall system”.

1.3.3.2 Because ordinary concrete shear walls are not permitted by ASCE 7 for buildings in SDC D, E, and F, the ICF walls shall comply with all requirements for “special reinforced concrete shear walls” in the CBC and ACI 318.

1.4 Wall Details

Concrete protrusions/extensions on the concrete wall surfaces intended to provide structural supports and anchorage for mechanical, electrical, and architectural components as indicated in Section 3.2 shall be designed and detailed as corbels or other code recognized structural elements.

1.5 Development and Lap Splice Lengths

The impact of the frequently spaced cross-tie webs on the development and lap splice lengths of horizontal reinforcement bars shall be accounted for. DSA will consider this impact to be accounted for if the development and lap splice lengths are increased by the sum of the thicknesses of the cross-tie webs that occur over the respective length.

1.6 Construction Documents

The following information shall be shown on the DSA-approved construction drawings for projects with flat wall ICF systems. Should modification of any of this information be proposed or required during construction, a Construction Change Document (CCD) shall be submitted to and approved by DSA prior to proceeding with the modification. Refer to *IR A-6: Construction Change Document Submittal and Approval Process*.

1.6.1 Concrete mix design requirements.

1.6.2 Reinforcement placement requirements per Section 2.3.2 below.

1.6.3 Location of vertical rebar splices.

1.6.4 Details specifying the attachment of wall finishes in accordance with Section 3.1 below including the following:

1.6.4.1 Spacing and edge distance of fasteners attached to the vertical cross-tie flanges.

1.6.4.2 Drawings shall require cross-tie flange locations be positively marked on the surface of the insulation board to ensure proper fastener edge distance is maintained.

1.6.4.3 Fastening details shall be provided for horizontal joints and top/bottom termination of wall finishes when required due to the absence of a horizontal substrate for attachment and cross-tie flange spacing exceeding fastener spacing requirements. Example locations include but are not limited to horizontal reveals, top of wall, top of door openings, top and bottom of windows, outside corners of walls, etc.

1.6.4.4 Fastening details shall be provided where cutting of cross-ties is necessary to facilitate installation of reinforcement (e.g., lintels, pilasters, wall corners, etc.) or to comply with other requirements.

1.6.5 Details specifying the attachment of nonstructural components supported by the wall in accordance with Section 3.2 below. When post-installed anchors are specified, details shall indicate any measures required to locate/avoid wall reinforcement and perform quality assurance testing (e.g., removal of insulation board, etc.).

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1.6.6 Viewport locations per Section 4.3 below, and details specifying the repair of insulation board if required for fire rating or thermal performance.

1.6.7 Mockup panel quantity, dimensions, thickness, and reinforcement configuration per Section 4.4 below. Indicate if the mockup panel is required to demonstrate installation of exterior wall finishes.

2. INSTALLATION

ICF wall systems shall be installed in accordance with the CBC, DSA-approved construction documents, evaluation report, manufacturer requirements and recommendations, and this section.

2.1 Erection

ICF systems shall be erected by installers qualified per Section 4.1 below.

2.1.1 Proper alignment of the forms shall be maintained during erection and concrete placement.

2.1.2 In applications where cross-tie flanges are used for the attachment of wall finishes, flanges shall be vertically aligned at all locations over the full height of the wall unless other methods demonstrate to the satisfaction of DSA that blind connections achieve positive connections at all locations and offsets.

2.2 Concrete Mix

Due to the size and number of cross-ties in ICF systems, concrete flow is restricted and may cause voids within the concrete, especially in areas of congested reinforcement such as columns, pilasters, jambs, lintels, boundary elements, and wall corners.

2.2.1 Concrete mix design shall have a minimum slump of 6 inches. DSA recommends a concrete mix design that yields “flowing concrete”, which is defined by ACI Concrete Terminology (ACI CT) as “a cohesive concrete mixture with a slump greater than 7-1/2 inches”, at the final discretion of the SEOR.

2.2.2 Concrete mix design shall conform to ACI 318 Section 26.4, ACI Specifications for Structural Concrete (ACI 301) Article 4.2.3, and ACI Guide to Evaluation of Strength Test Results of Concrete (ACI 214R).

2.2.3 Water reducing admixtures shall comply with ASTM C494. Plasticizing admixtures shall comply with ASTM C1017.

2.2.4 The concrete mix shall demonstrate the ability to be properly placed and consolidated without segregation or pockets through the construction of mockup panels per Section 4.4 below. Concrete mix shall be adjusted if segregation or pockets are discovered during examination of mockup panels, unless a separate cause is determined and addressed (e.g., consolidation methods).

2.2.5 Maximum aggregate size shall be 3/8-inch or larger when permitted by the evaluation report. Aggregates shall comply with CBC Section 1903A.5.

2.3 Reinforcing Steel Placement

Placement of reinforcing steel in the concrete walls shall comply with ACI 318 Section 26.6.2.

2.3.1 Vertical and horizontal reinforcing steel shall be secured to prevent movement and dislodgement during concrete placement.

2.3.2 If vertical and horizontal reinforcing steel is not be tied together as recommended by the Concrete Reinforcing Steel Institute (CRSI) Construction Technical Note CTN-G-2-15, it shall be

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demonstrated through the mockup panels that the reinforcement bars have not displaced during concrete placement. Destructive investigation (i.e., cutting, coring, or chipping as required) of the mockup panels shall show the reinforcement bar tolerances per ACI 318 Section 26.6.2 are maintained.

2.3.3 Wet stabbing/setting of vertical reinforcing is not allowed.

2.3.4 Bar placement methodology in accordance with Section 2.3.2 above and splice locations of vertical bars per Section 1.6.3 above shall be coordinated with the type of ICF system and construction joint locations used on the project.

2.4 Concrete Placement

Concrete shall be placed in a manner to avoid segregation, and to work thoroughly around reinforcement, embedded fixtures, and into the corners of forms.

2.4.1 The maximum pour height shall be 4-feet per day. All pours shall be consolidated.

2.4.2 It is the contractor's responsibility to select the appropriate means of consolidation to ensure proper concrete consolidation is achieved. All vibratory units shall be checked before starting work and periodically during construction to verify that they are working properly in accordance with the standards noted above and to ensure proper consolidation occurs continuously.

2.4.3 Between pours, a horizontal construction joint shall be formed by stopping the pour 1-1/2 inches below the top of ICF forms. Construction joints shall be cleaned and roughened per ACI 318 Section 18.10.9.

2.4.4 Supplemental backing or other means of form bracing shall be provided at all locations where the cross-ties are cut or damaged and at locations of blow outs.

2.5 Repair of Defective Work

When defective concrete or wall construction is identified within the ICF system, the design professionals shall prepare a CCD to specify the required repair work and any associated tests and inspections. In accordance with IR A-6, the CCD shall be reviewed and approved by DSA prior to commencing with the repair work.

3. ATTACHMENT OF NONSTRUCTURAL COMPONENTS

Although the ICF systems remain in place, they shall not support any structural loads or to seat any connectors such as screws, bolts, and anchors except as allowed by the ICF evaluation report.

3.1 Wall Finishes

Attachment directly to the EPS insulation panels is not permitted. Many interior (e.g., drywall) and exterior (e.g., metal lath and plaster) wall finish materials may be attached to the vertical cross-tie flanges when permitted by the evaluation report and manufacturer recommendations in accordance with the requirements of this section.

3.1.1 Adhered veneer applied directly to the EPS insulation panels is not permitted.

3.1.2 Anchored veneer fastened to the vertical cross-tie flanges is not permitted. Anchored veneer shall be anchored directly to the concrete wall.

3.1.3 Fasteners supporting approved wall finishes shall be substantiated by structural calculations for the code prescribed loads. Fastener capacity shall be as listed in the evaluation report based on testing in accordance with ASTM E2634. Additionally, fasteners shall comply with the following:

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3.1.3.1 Fastener type shall conform to ASTM C1063 Section 6.7.2.

3.1.3.2 Fastener type, size, and load capacity shall be listed in the ICF system evaluation report. Capacities shall be adjusted in accordance with IR A-5 Section 4.2 when applicable.

3.1.3.3 Fastener spacing in both the vertical and horizontal directions shall comply with ASTM C1063 Sections 7.9, 7.10.1.1, and 7.10.2.2.

3.1.4 Where cross ties have been cut or damaged, wall finishes shall be fastened directly to the concrete wall. Supplemental details submitted and approved per Section 2.5 above may be required.

3.1.5 It is recognized that plastic can become brittle at extreme low temperature (i.e., the glass transition temperature), which may compromise the expected fastener performance under code prescribed loads over the life of the structure. The design of fasteners for exterior wall finishes to cross-tie flanges shall take into account the local historical extreme low temperatures. At sites with a ground snow load greater than zero, the following documentation is required:

3.1.5.1 The design professional shall obtain the historical extreme low temperature from the local authority where the project site is located. In lieu of a document from the local authority, the design professional may provide a letter confirming the extreme low temperature from a nationally recognized weather service agency (e.g., the National Oceanic and Atmospheric Administration).

3.1.5.2 The design professional shall obtain from the ICF manufacturer the continuous service temperature ranges for which the fastener capacities as published in the evaluation report are applicable and for which the ICF plastic can maintain continuous service.

3.1.5.3 If the local historical extreme low temperature is beyond the limits of the ICF manufacturer's reported continuous service temperatures wall finish shall be secured directly to concrete or code recognized backing material.

3.1.5.4 A copy of the documents from the ICF manufacturer and those defining the extreme low temperature shall be provided to DSA at time of initial project submittal for plan review.

3.1.6 Where the locations of the vertical cross-tie flanges cannot be adequately marked or remarked thereby hindering verification of proper fastener installation as determined by the mockup panel program described in Section 4.4 below, alternative means for wall finish attachment shall be designed and detailed. If alternate details were not included on the DSA-approved construction drawings they shall be submitted, reviewed, and approved as a CCD in accordance with IR A-6.

3.2 Building Components

Building components greater than 20 pounds shall be anchored into concrete with cast-in-place anchors, post-installed anchors, or blocking attached directly to the concrete wall. Calculations of anchor capacity shall account for the eccentricity resulting from the thickness of the insulation panel when applicable.

4. QUALITY ASSURANCE

Special inspections, sampling, and testing of concrete wall construction materials shall be in accordance with ACI 318 Section 26.12 as modified by CBC Section 1705A.3, Table 1705A.3, Sections 1905A.1.15, 1910A, and 1910A.5. Additionally, the following requirements shall apply.

4.1 Installer Qualifications

4.1.1 ICF system installers shall be trained by the ICF manufacturer when required by the evaluation report or installation manual. Proof of training shall be provided to the school district,

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design professional in general responsible charge, and project inspector prior to the start of laying forms.

4.1.2 Wall finish installers shall be trained by the ICF manufacturer when required by the evaluation report or installation manual. Trained installers should be able to recognize when a fastener is properly attached to the vertical cross-tie flanges.

4.2 Inspection

Continuous inspection by the project inspector and/or a special inspector certified by a state or nationally recognized organization accepted by DSA is required. All aspects of the ICF construction shall be inspected. Special attention shall be given, but not limited to, the following:

4.2.1 Prior to concrete placement, verify cross tie flanges are aligned vertically for the full height of the wall at all locations. This is to facilitate the installation of fasteners to the cross-tie flanges for wall finishes.

4.2.2 Verify cross-tie webs and flanges are not cut unless specifically permitted on the DSA-approved construction drawings.

4.2.3 Verify installation of fasteners for wall finishes to the cross-tie flanges including fastener type, size, spacing, and edge distance on the flange. The project inspector, special inspector, or lab technician working under the supervision of the project inspector or special inspector shall independently verify the fasteners of exterior wall finishes as follows:

4.2.3.1 Turn the fasteners with a screwdriver, confirm engagement into the cross-tie flange, and verify the fastener does not spin freely indicating it has missed the cross-tie flange.

4.2.3.2 Verification by screwdriver shall be performed on 20 percent of the first 1,600 fasteners, 10 percent of the next 1,900 fasteners, and 5 percent of fasteners thereafter.

4.2.3.3 If any fastener is found to have missed the cross-tie flange, all previously unchecked fasteners installed by the same person shall be verified until 20 consecutive fasteners are found acceptable, after which the verification frequency defined in Section 4.2.3.2 above can be resumed.

4.2.3.4 All fasteners without proper engagement to the cross-tie flange shall be replaced.

4.2.4 Verify ICF wall construction is performed in accordance with the accepted mockup panels including the following characteristics. Refer to Section 4.4 below for mockup panel requirements.

4.2.4.1 Same personnel performing the work.

4.2.4.2 Same materials and concrete mix design used.

4.2.4.3 Same concrete placement and consolidation procedures used.

4.3 Verification of Concrete Consolidation

Unlike concrete construction with conventional formwork, in ICF construction the insulation panels are not removed after concrete curing thus preventing visual inspection for surface voids. To account for this precluded special inspection, concrete consolidation shall be verified in local regions by removing portions of insulation board to create "viewports" as described in this section.

4.3.1 Concrete consolidation shall be verified through viewports, which are created by cutting and removing sections of the insulation panels between cross-tie flanges. Viewports shall be at least 6-inch by 12-inch.

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4.3.2 The SEOR shall select the locations for viewports and show them on the construction drawings. Viewports shall be provided at typical walls and special conditions at the frequencies indicated below.

4.3.3 At typical walls, 3 viewports shall be provided per wall elevation and for each 5,000 square feet (SF) of wall surface area.

4.3.4 At special conditions prone to greater congestion of reinforcement such as wall corners, pilasters, lintels, columns, wall boundary elements, and window/door openings, viewports shall be provided in at least 25% of elements with a minimum of 5 locations for each type.

4.3.5 Additional viewports will be required when voids or significant cracks are discovered. A CCD shall be prepared by the design team and approved by DSA to define the scope of additional viewports. Repair of defective concrete shall be in accordance with Section 2.5 above.

4.3.6 The following examples illustrate how to determine the required number of viewports:

4.3.6.1 A typical wall with a surface area of 400 SF requires 3 viewports: minimum 3 viewports per elevation.

4.3.6.2 A typical wall with a surface area of 6,000 SF requires 4 viewports: $6,000 \text{ SF} \div 5,000 \text{ SF} = 3.6$, rounded up to 4 viewports.

4.3.6.3 A building with 60 pilasters (special condition) requires 15 additional viewports for pilasters: $25\% \text{ of } 60 \text{ pilasters} = 15 \text{ viewports}$.

4.3.6.4 A building with 14 pilasters (special condition) requires 5 additional viewports for pilasters: $25\% \text{ of } 14 \text{ pilasters} = 3.5$, rounded up 4, with a minimum of 5 viewports per special condition type (pilasters).

4.4 Preconstruction Mockup Panels

ICF mockup panels shall be constructed, inspected, and tested prior to construction of permanent ICF walls in accordance with this section. The objectives of the mockup panel program are to ensure proper concrete consolidation, validate the installation procedure, confirm reinforcement bar positions remain within the tolerances required by ACI 318 when Section 2.3.2 above applies, and demonstrate adequate attachment of exterior wall finishes to the vertical cross-tie flanges when applicable.

4.4.1 The project inspector and special inspector (when applicable) shall be present during the construction of the mockup panels.

4.4.2 Mockup panels shall have a minimum width of 10-feet and a minimum height of 4-feet. A minimum of 2 mockup panels shall be prepared for each thickness of concrete.

4.4.3 Mockup panels shall be representative of the specified design with reinforcing configurations representing the most congested conditions (e.g., columns, pilasters, lintel, jamb, wall corners, etc.).

4.4.4 Mockup panels shall be constructed by the same personnel with the same equipment as the permanent ICF wall construction.

4.4.5 Mockup panels shall be constructed with the same mix design used in the permanent ICF wall construction. If multiple mix designs are considered or will be used, separate mockup panels shall be constructed for each.

4.4.6 When required by the construction documents in accordance with Section 1.6.7 above, wall finishes shall be installed on the mockup panel to demonstrate adequate marking of cross-tie flanges and installation of fasteners. Refer to Section 3.1.6 above.

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4.4.7 After concrete placement and curing, the insulation shall be removed from mockup panels in their entirety. Concrete surfaces shall be thoroughly inspected for voids, segregation, and other defects. The inspector shall use impact sounding with a hammer to check for internal delamination.

4.4.8 After removal of insulation, mockup panels shall be cored, sawn, and examined to determine the adequacy of concrete consolidation and reinforcement bar position.

4.4.9 A minimum of 3 core samples shall be taken from each mockup panel and tested for compressive strength by the laboratory of record.

4.4.10 Results of the examination and tests described above shall be reviewed by the SEOR and submitted to DSA. The SEOR shall notify DSA of his/her acceptance or rejection of the preconstruction mockup panel results. DSA will document concurrence with or objection to the findings of the SEOR in the field engineer's field trip notes.

4.4.11 Permanent ICF wall construction may commence upon acceptance of the mockup panel results by the SEOR and DSA concurrence.

4.4.12 Rejection of the mockup panel results by the SEOR will require adjustment to the construction and additional mockup panels for further validation.

5. FIRE AND LIFE SAFETY

When a fire-resistance-rating is required of the wall for the type of construction or other provisions in the CBC, fire resistive ratings shall be as indicated in the manufacturer's evaluation report in accordance with IR A-5 or other listing by a nationally recognized or State Fire Marshal (SFM) recognized testing laboratory. Provide the ICF manufacturer supporting test data and associated restrictions on the use of their products in fire-resistance-rated assemblies.

5.1 Fire Rated Walls

Provide on the plans a manufacturer's construction/installation detail and tested assembly number for fire-resistance-rated assemblies from a nationally recognized or SFM recognized testing laboratory. The components and installation details must conform in every respect with the listed detail and number, or applicable evaluation report. Details shall clearly depict all components, including insulation materials, framing and attachment of the design so that the assembly can be constructed and inspected accordingly.

6. ACCESSIBILITY

The total wall thickness may affect door maneuvering clearances at recessed doors and gates; refer to CBC Section 11B-404.2.4.3. Appropriate details shall be provided on plans to assure compliance with all applicable code requirements.

REFERENCES:

2019 California Building Code (CBC) Chapter 11B, and Sections 1613A.2.5, 1705A.3, 1903A.4, 2603

This IR is intended for use by DSA staff and by design professionals to promote statewide consistency for review and approval of plans and specifications as well as construction oversight of projects within the jurisdiction of DSA, which includes State of California public schools (K-12), community colleges and state-owned or state-leased essential services buildings. This IR indicates an acceptable method for achieving compliance with applicable codes and regulations, although other methods proposed by design professionals may be considered by DSA.

This IR is subject to revision at any time. Please check DSA's website for currently effective IRs. Only IRs listed on the webpage at <http://www.dgs.ca.gov/dsa/publications> at the time of project application submittal to DSA are considered applicable.